IMPROVEMENTS ON THE TEXTURE
OF ARIZONA GROWN POTATOES

by
Bertha Josefina Rodriguez Terrazas

A Thesis Submitted to the Faculty of the
DEPARTMENT OF NUTRITION
AND FOOD SCIENCE
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
WITH A MAJOR IN FOOD SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

1980
STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Bertha J. Rodriguez

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Ralph L. Price
Associate Professor of Food Science

April 18, 1980
Dedicated to

those who have always given me their
best in understanding, counsel and friendship

my parents

Bertha and Ignacio
ACKNOWLEDGMENTS

I would like to express my appreciation for the guidance furnished me by the members of my committee, Dr. Ralph L. Price, and Dr. Warren Stull. In addition, the personal support provided by Dr. Paul M. Bessey has been instrumental in the completion of this thesis.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>viii</td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. REVIEW OF LITERATURE</td>
<td>3</td>
</tr>
<tr>
<td>Chemical Composition of Potatoes</td>
<td>4</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>5</td>
</tr>
<tr>
<td>Nitrogenous Compounds</td>
<td>12</td>
</tr>
<tr>
<td>Lipids</td>
<td>14</td>
</tr>
<tr>
<td>Inorganic Constituents</td>
<td>14</td>
</tr>
<tr>
<td>Texture of Potato Tubers</td>
<td>15</td>
</tr>
<tr>
<td>3. MATERIALS AND METHODS</td>
<td>19</td>
</tr>
<tr>
<td>Preparation of Samples</td>
<td>19</td>
</tr>
<tr>
<td>Specific Gravity Determinations</td>
<td>21</td>
</tr>
<tr>
<td>Chipping Quality Determination</td>
<td>21</td>
</tr>
<tr>
<td>Texture: Sloughing Determination</td>
<td>23</td>
</tr>
<tr>
<td>Chemical Composition Determinations</td>
<td>25</td>
</tr>
<tr>
<td>4. RESULTS AND DISCUSSION</td>
<td>28</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>28</td>
</tr>
<tr>
<td>Chemical Composition</td>
<td>30</td>
</tr>
<tr>
<td>Chipping Quality</td>
<td>34</td>
</tr>
<tr>
<td>Sloughing of Potato Tubers</td>
<td>34</td>
</tr>
<tr>
<td>Calcium and Magnesium Determinations</td>
<td>43</td>
</tr>
<tr>
<td>5. CONCLUSIONS</td>
<td>47</td>
</tr>
<tr>
<td>LIST OF REFERENCES</td>
<td>49</td>
</tr>
</tbody>
</table>
## LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Standard curve for protein determination using the bromophenol-blue dye binding method and bovine albumin serum as standard protein</td>
<td>31</td>
</tr>
<tr>
<td>2.</td>
<td>Effect of soak period on sloughing for three specific gravity tubers cooked in distilled water</td>
<td>37</td>
</tr>
<tr>
<td>3.</td>
<td>Effect of soak period on cooked potato weight for low specific gravity tubers</td>
<td>40</td>
</tr>
<tr>
<td>4.</td>
<td>Effect of soak period on cooked potato weight for medium specific gravity tubers</td>
<td>41</td>
</tr>
<tr>
<td>5.</td>
<td>Effect of soak period on cooked potato weight for high specific gravity tubers</td>
<td>42</td>
</tr>
<tr>
<td>6.</td>
<td>Possible effect of salts on sloughing of potato slices previously soaked in water</td>
<td>46</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table | Page
-----|-----
1. Proximate analysis of potatoes | 6
2. New and standard varieties grown at the University of Arizona Mesa Experiment Station in a semicommercial demonstration during spring seasons of 1978 and 1979 | 20
3. Classification and specific gravity of ten selected Arizona-grown potato varieties | 29
4. Comparison between total solids values obtained using two different methods for determining total solids | 32
5. Approximate composition of ten selected potato varieties grown in Arizona | 33
6. Chipping characteristics of ten selected Arizona-grown varieties | 35
7. The effect of various salts in the sloughing of tubers previously soaked in distilled water | 39
8. Calcium and magnesium content of cooking media before and after cooking unsoaked and soaked potato slices | 44
ABSTRACT

Ten Arizona grown potato varieties, including three standard and seven new and advanced clones were evaluated for specific gravity, chemical composition, chipping quality and texture of the tubers after cooking.

Two chemical composition of the tubers varied widely, but within the predicted range according to their specific gravity. Six of the varieties (five new and one standard) were suitable for manufacture of potato chips.

The texture of cooked tubers was evaluated objectively. Tuber disintegration as affected by several cooking solutions was assessed. The sloughing of potatoes soaked for 0, 2, and 4 hours and cooked in distilled water was used as control. The influence of ion removal and single anion and cation replacement upon tissue sloughing was evaluated. Citrate, sodium, and potassium increased sloughing, while calcium, and magnesium resulted in less sloughing than that obtained with distilled water. Using soaking water as cooking media decreased sloughing in the potato tissue slices which were soaked for 2 hours. When mixtures of either calcium and magnesium with the soak water were used as cooking media, sloughing decreased in a linear manner according to the length of the soaking period. The results indicate that the effectiveness of divalent cations in avoiding sloughing is directly related to the starch content of the potato tubers.
CHAPTER 1

INTRODUCTION

The potato, *Solanum tuberosum*, is an annual, dicotyledonous plant belonging to the Solanaceae family. It is sometimes regarded as a potential perennial because of its ability to reproduce vegetatively by means of tubers. Tubers arise on underground stems and new shoots are produced from them (Smith 1977).

The potato comes from South America where the natives brought potatoes under cultivation possibly 2,000 years before the Spanish conquest. At the beginning of the eighteenth century, two potato varieties were brought to the United States from Ireland. During the nineteenth century, thousands of varieties were originated by American plant breeders, but only a relatively few were introduced and proved for large scale production (Salaman 1949).

During the early years potato production was centered in New England and the Midwest. As these areas developed toward the West, the potato was grown commercially in every state in the United States. Currently, Idaho and Washington lead in producing potatoes in the West, while Maine leads in the East (U.S.D.A. 1976).

Arizona grows between 4,000 and 6,000 acres of potatoes each year. Arizona is listed as the twenty-second ranking potato producer in the United States (U.S.D.A. 1978A). Usually, certified seed grown in
the Northern States is planted in the state, and yield is somewhat above the national average. Seventy percent of Arizona's production is marketed for chips which requires low sugar and high starch content. The rest are termed early potatoes and have a relatively low starch content (Pew et al. 1979).

During 1978 and 1979, seven Nebraska grown varieties and advanced clones and three standard varieties were included in the semi-commercial demonstration plantings at the Mesa Experiment Station of the University of Arizona. All the varieties were planted and grown between February 21 and June 12, 1979, following commercial production practices. Comparative characteristics and standards of tuber quality, composition and textural response under cooking conditions have not been established for these winter-spring grown varieties. The purpose of this study was to evaluate the chemical composition and the culinary characteristics of these new Arizona grown potatoes. It was felt important to evaluate possible differences which might have developed in the original Nebraska-grown varieties due to fertilization practices and environmental conditions.
Potato is not usually considered as a complete food, and is popularly identified as fattening. Even though the general attitude toward potatoes is adverse, their consumption as a staple food in the United States is high. Potatoes are one of the most consumed food items in this country (U.S.D.A. 1979). The per capita consumption of potatoes in the United States was 121.6 pounds during 1978. The amount of processed product consumption was higher than the amount of fresh product consumed during the same year (U.S.D.A. 1978A). Also, more processed potato products are being consumed every year due to processing efficiencies and preparation convenience (Smith 1977).

Like other fruits and vegetables, the potato contains vitamin C, plus many other vitamins and minerals important in the daily diet like vitamin B₆ and iron (U.S.D.A. 1978B).

Commercial production of potatoes occurs in every state. Although more potatoes are used as food, there are clear differences between those consumed as table stock and those consumed in processed forms. Many different varieties are grown and harvested depending on their final use. The difference between processed and table stock potatoes depends on their chemical composition; however, it is not a common practice to analyze tubers annually in order to determine their use (Smith 1977).
The most common method used to categorize the tubers for food consumption is by determination of specific gravity (Smith 1950B). The specific gravity of the tubers has long been used for rapid estimation of their chemical components, particularly starch (Smith 1950A). It is generally accepted that, in a given variety, specific gravity which is a measure of the dry matter or starch content of potatoes is highly correlated with the characteristics of the finished product (Smith 1977).

An inexpensive, rapid, and accurate method of determining specific gravity of potatoes was made possible by the development of the potato hydrometer (Smith 1950B). The method is excellent for determining the texture of the home prepared potatoes, as well as the final characteristics of the processed products. A positive correlation between specific gravity and texture has been demonstrated (McBean, Coote, and Christie 1973).

The specific gravity of commercial potatoes varies from 1.060 to 1.100 (Smith 1977). Low specific gravity tubers are highly recommended for consumption as fresh material. On the other hand, in selecting potatoes for processing, except for canning, it is important that tubers of high specific gravity be chosen (Davies and Dixon 1976). In both cases, there is a direct relationship between specific gravity and the chemical composition.

Chemical Composition of Potatoes

The chemical composition of potatoes varies with variety, soil type, area where grown, cultural practices, maturity, method of vine kill, storage and other factors (Smith 1977). As a result, it is almost
impossible to present meaningful data of the chemical composition of potatoes unless all or most of the factors listed above are considered.

Most available data on chemical composition of the potato only approximate various sets of growing conditions. According to Talburt et al. (1975) the chemical composition of potatoes is only a random combination of the factors listed above and does not represent the real composition of a given variety, time or place (Table 1).

Carbohydrates

There are several types of carbohydrates in the potato tuber including starch, glucose, fructose, sucrose, cellulose, pectic substances and hemicellulose.

Starch. It represents 65 to 80% of the dry weight of the potato tuber and in caloric terms is the most important nutritional component (Schwimmer and Burr 1967). The content, physical and chemical characteristics of the starch are not only intimately associated with various factors involved in the quality of the processed products, but these properties also dictate conditions for the operation of a given process (Smith 1977).

In the raw tuber, starch is present as microscopic granules in the interior of the cell walls. The granules are of ellipsoidal shape and average 60 by 100 microns (Geedes, Greenwood and Mackenzie 1965). According to Reeve (1968), the starch granules vary in size and distribution within the tuber tissue. Smaller granules have been related directly to dry season, small tubers, immaturity, and prolonged post-harvest storage (Briant, Personius, and Cassel 1945). Using appropriate procedures, the starch granules can be isolated in the laboratory
Table 1. Proximate Analysis of Potatoes

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>%</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>77.5</td>
<td></td>
<td>63.2-86.9</td>
</tr>
<tr>
<td>Total solids</td>
<td>22.5</td>
<td></td>
<td>13.1-36.8</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>19.4</td>
<td></td>
<td>13.3-30.56</td>
</tr>
<tr>
<td>Protein</td>
<td>2.0</td>
<td></td>
<td>0.7-4.6</td>
</tr>
<tr>
<td>Fat</td>
<td>0.1</td>
<td></td>
<td>0.02-0.96</td>
</tr>
<tr>
<td>Ash</td>
<td>1.0</td>
<td></td>
<td>0.44-1.9</td>
</tr>
</tbody>
</table>
The dry matter of the granules contain 99.5% starch, 0.3% ash, and 0.01% N (Schwimmer and Burr 1967).

Potato starch consists of two components: amylose and amylopectin (Schwimmer 1953). Amylose is the long, straight chain polymer of anhydroglucose units, while amylopectin is the branched chain compound (Harper, Rodwell, and Mayes 1977). Amylose has an average degree of polymerization of 1,000 to 5,000 and amylopectin of 100,000 (Potter and Hassid 1948).

Whole starch granules of potato contain about 20% amylose and 80% amylopectin (Banks and Greenwood 1959). The ratio of amylose and amylopectin is 1:3 and seems to be fairly constant, although slight varietal differences have been reported (Schwimmer et al. 1954). This ratio is affected by neither time nor temperature of storage (Smith 1977), but it increases with increases in granule size during maturation of the tuber (Geedes et al. 1965).

Of all the minor constituents of the starch granule, only phosphorus has been shown to be chemically combined with the starch (Posternak 1951). Brautlecht and Getchel (1951) reported that the average composition of the potato starch ash is as follows: PO$_4$ 54.47%, CaO 36.05%, SiO$_2$ 3.9%, K$_2$O 2.01%, MgO 1.82%, Na$_2$O 1.39%, and CO$_3$ 0.31%. Although P represents only a small percentage of the starch granule, as much as one-third of the total P may be combined with starch (Schwimmer, Bevenue, and Weston 1955). Of the other minor components, the trace or N present apparently comes from the proteins of the cytoplasm (Schwimmer and Burr 1967).
It has been repeatedly demonstrated since early studies in the 1940's, that there is a close correlation between specific gravity, total solids content, and starch concentration in the potato tuber. The reason is because starch represents the greatest percentage of the dry matter and its concentration is fairly constant. All of the parameters which increase or decrease the specific gravity and total solids in the tuber, also increase or decrease respectively the starch content either on wet weight basis or dry weight basis (Smith 1977, Talburt and Smith 1967).

Starch is the component of the potato tuber which has been studied most thoroughly since its characteristics are extremely important for the finished product obtained either at industry level or in the kitchen. Some of the properties of potato starch that will be considered in this work are:

a) Extremely hygroscopic material (Willigen 1960).

b) Specific optical rotation for sodium light: \([\alpha]_D = 204^\circ\) (Kerr 1950).

c) Swelling power at 95°C (loss of birefringence): 1000 (Lee 1975).


e) Solubility at 95°C: 82% (Lee 1975).

f) Critical concentration value (weight in grams of dry starch necessary for use with 100 ml of water to form a paste at 95°C): 0.1 (Lee 1975).
**Glucose, Fructose, and Sucrose.** They are the major sugars of the potato; however, trace amounts of ketoheptose, melibiose, male- zitose, raffinose, fructosan, and inositol have been detected (Schwimmer et al. 1954).

All of the three major sugars are in the alcohol-soluble fraction of the potato tubers (LeTourneau 1956). Their concentration varies from trace amounts to as much as 10% of the dry weight of the tuber (Brautlecht and Getchel 1951, Schwimmer and Burr 1967).

Freshly harvested potatoes contain very little sugar (Smith 1977); immature tubers have a much higher content of sucrose than mature tubers (Talburt and Smith 1967). According to Weaver et al. (1978), sucrose is evenly distributed in the tuber, glucose content is high in the core tissue, and fructose is high in either bud-end or stem-end, but not in the core of the tuber.

During postharvest storage, sugar content of potatoes is mainly affected by two factors: variety and temperature (Talburt and Smith 1967). The changes in sugar content occur in the tubers as a result of storage conditions. Starch is broken down to glucose at low temperature storage (30-40°F). Fructose, on the other hand, comes from either starch or glucose, and sucrose is formed after free glucose and fructose react. When the storage temperature rises, a reconversion of sugar to starch occurs increasing the total starch concentration; however, the percentage of starch may also increase if all the sugar is lost through respiration of the tubers when the temperature is too high (Smith 1977, Talburt and Smith 1967).
There is an inverse relationship between sugar content and the specific gravity of the potato tubers (Agle and Woodbury 1968). Since starch and specific gravity value are directly related, and since sugar content increases while starch decreases, sugars and specific gravity should have an inverse relationship.

Glucose and fructose are reducing sugars because they have a free carbonyl group, which is able to react under a wide variety of conditions. Sucrose is a non-reducing sugar being devoid of a free carbonyl group (Lehninger 1970).

During processing the reducing sugars are extremely important because they may react and impart undesirable properties to the finished product. For instance, in the manufacture of potato chips, the amount of reducing sugars present is closely related to the color produced during processing, and in dehydrated products, to the darkening that may take place during subsequent storage (Schwimmer et al. 1957). In this case the reducing sugars react with free amino groups of amino acids in proteins producing brown compounds. This kind of reaction is described as Maillard or non-enzymatic browning (Talburt and Smith 1967).

In summary, increased reducing sugar content has a negative effect upon quality and processing of the finished product and is related to specific gravity (Schwimmer and Burr, 1967). As a rule, potatoes of high specific gravity, high starch content, high total solids content, and low sugar content are the most desirable for processing, except for canning.
Pectic Substances. Pectins are derivatives of polysaccharides (Lee 1975) which are of considerable interest in foods of plant origin (Fennema 1976). Pectic substances are polysaccharides of D-galacturonic acid or of its methylester (Meyer 1978). According to Keijbets, Pilnik, and Vaal (1976), the pectic materials in the potato are esterified about 50-55%. Although D-galacturonic acid is the main sugar component of pectic materials, other sugars including D-galactose, L-arabinose, and D-xylose are also present as constituents (Pigman, Horton, and Herp 1970).

Pectic materials are found in the primary cell wall and intercellular layers of the tubers. The difference between those present in the cell walls and those in the intercellular layers is that the former tend to occur with a part of the acid groups as salts (Aspinal 1970). It has been shown that pectins are found in cell walls as cementing materials in the middle lamella, as Ca salts of pectinic acids (Bettelheim and Sterling 1954B). Warren and Woodman (1974) showed that calcium (Ca) salts are more concentrated in the external tissues of the potato tuber than in the interior tissues.

The uronide or pectinic content of raw potatoes is fairly constant ranging from 0.38% to 0.45% (Warren and Woodman 1974). Keijbets and Pilnik (1974) demonstrated that the pectinic substances vary slightly with the specific gravity, but the higher the specific gravity, the higher the possibilities for synthesis of polysaccharides such as starch and pectic materials.
The pectic substances have usually been assumed to fulfill a structural role in plant tissues, and adhesiveness causing firmer tissues. The chemical evaluation of the structural strength of pectins takes account of the amount of polyuronide, its degree of esterification, and the amount of pectins in the form of Ca salts (Warren and Woodman 1973, 1974).

**Cellulose and Hemicellulose.** Both cellulose and hemicellulose are components of the cell walls and cementing substances between the cells of the tuber (Smith 1977). While cellulose is present in the supporting membrane of the cell wall, hemicellulose occurs in the cell wall (Talburt and Smith 1967).

Cellulose is a high molecular weight polysaccharide formed by glucose residues combined through B1-4 linkages. The term hemicellulose covers a variety of plant polysaccharides other than cellulose, starch and pectic substances; some contain only unmodified pentose and/or hexose units, and others contain hexuronic acids (Fennema 1976).

Cellulose comprises 10 to 20% of the non-starch polysaccharides of the potato (Schwimmer and Burr 1967). Hemicellulose represents about 1% of the total polysaccharides of the potato, according to Hoff and Castro (1969).

**Nitrogenous compounds**

About 1 to 2% of the total dry weight of the potato is of nitrogenous compounds (Talburt et al. 1975). Only one-third or one-half of the total N is present as proteins (Smith 1977), the remaining N consists of amides, nitrogenous bases, and free amino acids (Chick and Slack 1949).
The nutritive value of the N of the potato tubers is high (Desborough and Weiser 1972). Kelly (1972) found that the biological value of the nitrogenous compounds in the potato are superior to that of wheat and other horticultural crops.

About 90% of the nitrogenous compounds is soluble in the usual aqueous solutions, and the insoluble residue is associated with the skin of the tubers (McCay and McCay 1967).

Five protein fractions were separated, identified, and evaluated by Lidner, Jaschick, and Korpaczy (1960). The complete nutritional value was made by Kapoor, Desborough and Li (1975), partial evaluations were made much earlier by Chick and Slack (1949). The identified protein fractions are: tuberin (Osborne and Campbell 1895), globulin ortubennin (Chick and Slack 1949), albumin, prolamine, and glutelin (Lidner et al. 1960). The molecular weight of the protein fractions were estimated by gel electrophoresis as being between 16,500 and 29,000, using comparison with calibration proteins and their mobility (Seibles 1979).

The amino acid composition of potatoes shows substantial levels of essential amino acids when compared with egg proteins (Kaldy and Markakis 1972). The biological value of the potato proteins range from 46 to 79 (Kapoor et al. 1975); the limiting amino acids are methionine and/or isoleucine (Rexen 1976). Methionine is the limiting amino acid when compared either with FAO reference protein and egg protein, while isoleucine is limited only when compared with egg protein. As a special characteristic of potato proteins, lysine and leucine are much higher than both reference proteins. The tryptophan,
phenylalanine, threonine and valine content of potato protein is comparable to egg protein and higher than FAO reference protein (Kapoor et al. 1975, Kaldy and Markakis 1972).

Potato proteins may be recovered after industrial starch extraction from the discarded residues and used as protein supplement of human or animal diets (Rexen 1976).

Lipids

The average fat content of the potato is approximately 0.1% on a fresh weight basis, ranging from 0.02% to 0.2%. The concentration of lipids is greatest in the periderm and lowest in the vascular storage parenchyma (Schwimmer and Burr 1967).

Cotrufo and Lunsetter (1964) found that the fatty acids of the potato consisted of 41.3% linoleic acid, 24.9% palmitic acid, 19.4% linolenic acid, 6.6% oleic acid, 5.4% stearic acid, and 0.6% myristic acid. Trace amounts of caproic and lauric acids were detected by Kuznetzov and Nekrasova (1974).

The potato fat is relatively susceptible to oxidative deterioration (Burton 1949). Total lipids present in the tuber do not change during storage at low temperatures, but decrease significantly when stored at room temperature (Mondy, Mattick, and Owens 1963).

Inorganic constituents

The mineral content of potatoes varies widely with variety, maturity, and storage (Smith 1977). The minerals of the potato tubers vary from 0.44 to 1.9% of the wet weight basis (Talburt et al. 1975).
Potassium, phosphorus and chlorine are the most abundant minerals in the potato tuber (True et al. 1979). Potassium comprises 42 to 54% of the ash, and is found in the tuber in dissolved salt form in the liquid around the cells, some of which contain only starch (Brautlecht and Getchel 1951; True et al. 1979). Phosphorus and Cl are present in concentrations of 7 to 8% and 2.5 to 2.9%, respectively.

Other minerals and magnesium (Mg) (2.0-2.6%) which is more abundant in potatoes than calcium (Ca) (0.5 to 2.0%). Both minerals are present in the starch granules, but Mg is present only at low concentrations. Most of the Mg is present nearer to the surface of the tuber (Woodman and Warren 1972; Brautlecht and Getchel 1951).

Sodium (less than 1%) is present as NaCl in the potato juice and in the starch (True et al. 1978).

Traces of Zn, Cu, Al, Fe, B, Mn, Mo, and Se have been reported as present in the potato ash (True et al. 1979).

Potatoes provide 2% or more of the U.S.R.D.A./150 g serving of Cu, I, Mg, P, and Zn (True et al. 1978).

Texture of Potato Tubers

There are two general approaches to the investigation of potato texture. First is the identification of tissue textural features such as hardness, cohesiveness, and elasticity. Second is the relationship between those features and the chemical composition or processing treatments related to them. Both approaches complement one another, but rarely are found together.
In association with the various problems of potato technology, the texture of the cooked product has been studied for many years. Many scientists have demonstrated that there are at least two independent problems on the texture of cooked potato tissue (Bettelheim and Sterling 1954A, 1954B; Iritani, Powers, and Weller 1977, Warren and Woodman 1974). Those two features are described as mealiness or separation of a tissue on chewing, and sloughing or breakdown of the tissue while cooking (Bettelheim and Sterling 1954A, Warren and Woodman 1974).

Mealiness refers to the feel of the potato in the mouth. The potatoes, when mealy, are shiny in appearance, but feel dry and granular on the tongue (Sterling and Bettelheim 1954; Warren and Woodman 1974; Whittenberger 1951). The dependence of mealiness on the flow characteristics of cooked potato tissue is highly associated with subjective interpretations, and objective evaluations are rarely made (Schwelfelt, Brown, and Troop 1955; Whittenberger and Nutting 1950).

Sloughing is the disintegration of tubers upon cooking (Warren and Woodman 1974). According to Sweetman (1941) sloughing results mainly from cell separation, and to a smaller extent, from cell rupture. When potato tissue is cooked, the cells become rounded and tend to separate one from another (Reeve 1954, Whittenberger and Nutting 1950). As a result, the tissue falls apart or sloughs (LeTourneau, Zaehringer, and Potter 1962).

The potato tubers slough at different rates depending on their specific gravity. Tubers of high specific gravity slough more than tubers of low specific gravity (Whittenberger 1951). This difference
is due to the higher starch content of high specific gravity tubers (Whittenberger 1951, Talburt et al. 1975).

Starch gelatinizes during heating (Lee 1975). Before gelatinization occurs, the starch begins to swell and increases in volume (Fennema 1976). When the starch content is high in a cell, the cell will increase in size during heating. The cell wall may not be able to retain its contents and will rupture, but before rupture occurs, the cells tend to separate one from another (Whittenberger 1951).

The cell walls in the potato tubers consist of microfibrils of cellulose fixed firmly by pectins and hemicellulose (Northcote 1958). While cooking, a series of changes occur in the cell wall. First, the cell wall hydrates and weakens (Warren, Woodman, and Gray 1975). Second, the pectic substances become soluble and are released into the cooking liquid (Keijbets et al. 1976; Hughes, Faulks, and Grant 1975A, 1975B). Third, the cell wall ruptures and releases ungelatinized starch into the cooking solution (Warren and Woodman 1973).

Potato tubers of low specific gravity have a starch content lower than those of high specific gravity; however, their protein content is higher (Smith 1977, Talburt et al. 1975). Russel (1952) and Heinze (1956) found that the protein content was inversely related to the susceptibility of potatoes to slough. When the tubers are high in protein, more N compounds and proteins exist in the cell walls, the ratio of proteins to polysaccharides is high and gives strength to the cell wall. Proteins coagulate on heating and increase the cohesiveness between cells which decreases their separation (Woodman and Warren 1972).
Low specific gravity tubers require more severe heating conditions (longer time) to break the cell walls and to slough (Zaehringer et al. 1963).

Various procedures to reduce sloughing have been used. The most common is the addition of soluble Ca salts which promote the intercellular adhesion of pectic materials by reacting with them and increasing their viscosity (LeTourneau et al. 1962). Also, Ca salts may increase the firmness of the starch grain (Reeve 1972).

Zaehringer et al. (1963) studied the possibility of decreasing the amount of sloughing by removing soluble salts from the tubers by soaking them in distilled water prior to cooking. During soaking, K is the main cation removed. While cooking, the removed cation may be replaced by Ca or other cations which increase the cohesiveness of the cells.

The techniques for reduction of sloughing are assumed to operate via cell wall mechanisms previously described; their limitations are due to the differences of cell wall thickness between potato varieties (Van Buren 1974).
CHAPTER 3

MATERIALS AND METHODS

Ten potato varieties, including 7 advanced clones and varieties plus 3 standard varieties, were grown in replicated plots at the University of Arizona, Mesa Experiment Station in Mesa, Arizona. They were harvested 112 days after planting, on June 12, 1979.

Each variety was represented by samples of 40 U.S. No. 1 grade tubers replicated four times. The varieties were characterized by several subjective properties (Table 2).

The ten varieties had not been previously subjected to chemical analysis and culinary evaluation. The 3 standard varieties had been characterized in other states where they grow, but not in Arizona. The other 7 were completely unknown since they are strains that are being tested for possible future release as commercial varieties. The 7 new varieties had been planted previously in Nebraska, but their characteristics may differ when grown in Arizona.

Preparation of Samples

The 40 samples (10 varieties in 4 replicates each) for analysis of chemical composition were prepared immediately after harvest. The tubers were subsampled by taking a transverse third of each tuber. The middle third of each was peeled by using a regular peeler, and sliced into transversal slices of 0.5 cm wide; the end two-thirds were
Table 2. New and standard varieties grown at the University of Arizona Mesa Experiment Station in a semicommercial demonstration during spring seasons of 1978 and 1979.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Skin Color</th>
<th>Shape</th>
<th>General Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced selections</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nebraska S1-3</td>
<td>White</td>
<td>Oval, smooth</td>
<td>Excellent type, size and yield</td>
</tr>
<tr>
<td>Nebraska A143.70-2</td>
<td>Red</td>
<td>Round</td>
<td>Excellent type, size and yield</td>
</tr>
<tr>
<td>Nebraska 118</td>
<td>Bright red</td>
<td>Oval</td>
<td>Good type, size and yield</td>
</tr>
<tr>
<td>A68678-1</td>
<td>Russet</td>
<td>Oval</td>
<td>Good type, size and yield</td>
</tr>
<tr>
<td>Denali</td>
<td>White</td>
<td>Round</td>
<td>Excellent type, size and yield</td>
</tr>
<tr>
<td>Nebraska A63.71-1</td>
<td>Russet</td>
<td>Oval</td>
<td>Excellent type, size and yield</td>
</tr>
<tr>
<td>Nebraska 42-1</td>
<td>Russet</td>
<td>Oval</td>
<td>Commercially acceptable type</td>
</tr>
<tr>
<td><strong>Standard varieties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red LaSoda</td>
<td>Red</td>
<td>Oblong</td>
<td>Good yielder</td>
</tr>
<tr>
<td>Kennebec</td>
<td>White</td>
<td>Elliptical to oblong</td>
<td>Good yielder</td>
</tr>
<tr>
<td>Norgold</td>
<td>Russet</td>
<td>Oblong</td>
<td>Good type, size and yield</td>
</tr>
</tbody>
</table>
discarded. Then 500 g of slices were weighed and immediately freeze- dried. Moisture was determined at the same time, and total solids were calculated by difference.

The remaining 30 tubers of each variety were stored at room temperature and samples were taken as needed for the texture measurements during the next 45 days until termination of the experiments.

**Specific Gravity Determinations**

Specific gravity was determined using a potato hydrometer developed by Smith (1950B).

The hydrometer is calibrated for an eight-pound sample. The potatoes were randomly chosen from storage and, after weighing, were placed in a wire basket. The basket was suspended from the bulb of the hydrometer. When the sample and apparatus were placed in a container with water, the correct specific gravity and total solids readings were obtained at the water level on the chart in the tube.

Specific gravity determination was made on the day following harvest on all 40 samples.

Replicated results were averaged. The 10 varieties were then separated into 3 groups. The members of each group had a specific gravity variation within a 0.005 range.

**Chipping Quality Determination**

Chipping quality was determined in order to classify the 10 Arizona grown potatoes for possible industrial use. It was evaluated following the mini-fry procedure developed by Dr. Robert O'Keefe at the
University of Nebraska in Lincoln, Nebraska, and using a kit provided by him.

The procedure was as follows: A fryer was filled with 3 quarts of "Wesson" vegetable oil, the thermostat was switched to "full on" position. A thermo-regulator probe was immersed in the oil and plugged into the fryer to control temperature regulator and set at 375°F. Five potatoes were randomly selected and a 1 inch slab was cut from each. The center of the potato, from end to end, was sampled using a double knife supplied by the kit. Two "plugs" were taken from each potato with a five-eighths inch plugger, sampling always the outer portion of the potato slab. After 5 plugs were inserted in the plugger, they were pushed out and deposited into a shuttle (2 fused plastic tubes) by means of a plastic rod. Then, a wash bowl was filled with H₂O and the fry basket was emersed into it. The slicer was placed on the basket with the blade side up. The plugs were sliced into "mini-chips" into the basket by moving the shuttle back and forth over the slicer blade. The mesh cover was placed in the basket and the H₂O was shaken out from the basket and slices. The basket was emersed into the hot oil slowly until the mesh cover in the basket was even with the cover of the fryer. The slices were fried for one minute and 45 seconds. The product was visually compared with the McLaughlin standard chart provided by Potato Chip International Institute (PCII) by placing the sample in a paper booth under the light provided in the cover of the carrying case.
Texture: Sloughing Determination

The standard method for objective evaluation of potato texture developed by Zaehringer et al. (1963) was used with some modifications.

When the sample was prepared, one tuber was peeled, cut transversally in thirds, sliced into 5 mm slices, and 50 g of slices obtained for one-third were used in each determination. The 2 end thirds were discarded. All tests were run in duplicate.

Detailed steps of the procedure were as follows: Fifty g lots from each of the 40 samples were soaked in 125 ml of distilled H$_2$O for 3 different periods: 0 hr, 2 hr, and 4 hr. After soaking in distilled water, the soak water was discarded and the slices were cooked in 600 ml of distilled H$_2$O at 98°C. The slices were cooked for different lengths of time, depending on their specific gravity. The group of lower specific gravity was cooked for 24 minutes, the medium specific gravity tubers for 21 minutes, and the high specific gravity tubers for 15 minutes. At the end of cooking, the slices were drained and washed three times with distilled water. The slices were brought to room temperature and weighed. Sloughing was calculated by the inverse relationship it had with the cooked potato weight. For instance, when a 100 g sample was cooked and weighed, its cooked potato weight was higher or lower than 100 g. If the weight was higher, it meant that the tuber did not disintegrate during cooking or it did not slough. On the other hand, if its weight decreased, the tuber disintegrated or sloughed during cooking.

Treatments involving different cooking liquids were modifications of the standard method. These cooking media used were:

a) 0.005 N CaCl$_2$ solution
b) 0.005 N NaCl solution

c) 0.005 N KCl solution

d) 0.005 N MgCl$_2$ solution

e) 0.005 N NaOH solution

f) 0.005 N citric acid solution

g) Soaking liquid

h) Soaking liquid: 0.005 N CaCl$_2$ solution

i) Soaking liquid: 0.005 N MgCl$_2$ solution

The calculations for all the treatments were as described in the standard method. The soaking liquid for g, h, and i treatments was obtained by soaking potato slices in distilled water for 2 hours. The liquid was then collected and frozen until needed.

Calcium and Mg were determined in the soaking liquid used in treatments g, h, and i before and after cooking. The cations were determined using a general quantitative method for the determination of hardness in water proposed by Brumblay (1969). Because Na and K were also present in the soaking liquid, the use of more sophisticated procedures was difficult to apply because of their interferences with Ca and Mg.

A typical procedure would consist of the following: For Ca, 50 ml of the sample was placed in a 250 ml beaker. Four ml of a phosphate buffer solution, 0.02 g of NH$_3$OHCl, 0.25 g NaCN, and 4 drops of eriochrome black T indicator were added. Then, the solution was titrated with a standard EDTA solution (1 ml EDTA = 1 mg Ca), and calculations were made using the following formula:

$$mg/1 \text{ of Ca} = \frac{ml \text{ EDTA used}}{ml \text{ sample}} \times \frac{mg \text{ Ca}}{ml \text{ EDTA}} \times \frac{1000 \text{ ml}}{1}$$
For Mg quantification 50 ml of sample was used. 100 ml of solution containing 1 g of \( \text{(NH}_4\text{)}_2 \text{C}_2\text{O}_4 \) were heated at 90°C and added to the sample. Then 2 drops of methyl red indicator, and 10 g of solid urea were added to the solution, and heated to boiling until the indicator changed from red to yellow. The solution was filtered and the filtrate treated in the same way than for Ca determination. The values for Mg were obtained through titration and Ca was found by calculation of difference.

**Chemical Composition Determinations**

Starch, proteins, reducing sugars and moisture were determined in this study to help in the classification and evaluation for commercial purposes of the 10 Arizona grown potato varieties.

Starch was determined by following the technique developed by Dimpler (1962) for materials containing high amounts of starch. A typical analysis was as follows: Two grams of freeze-dried tissue were weighed accurately into a test tube. Ten ml of an alcoholic solvent \( (1 \text{ g MgCl}_2 + 100 \text{ ml 95% ethanol + 900 ml distilled H}_2\text{O}) \) were added, and the tube was stoppered and shaken vigorously for 2 minutes. The mixture was filtered with suction through hard paper. The tube was rinsed while transferring the residue quantitatively, and the residue washed with 25 ml of alcoholic solvent, after which vacuum was applied until the residue was dry. The paper and residue were transferred to a 250 ml beaker, and 10 ml of \( \text{H}_2\text{O} \) was added. After maceration with stirring rod, 60 ml of \( \text{CaCl}_2 \) solution \( (550 \text{ g CaCl}_2 \text{ in 760 ml H}_2\text{O}) \) were added, and the liquid level was marked on the beaker. The beaker was
placed on a hot plate, and contents were brought to boil in 5 minutes while stirring. Boiling was continued for 30 minutes adding H₂O as needed to maintain the liquid level constant. The mixture was cooled to room temperature. The proteins present in the mixture were precipitated by adding 4 ml of SnCl₂ solution (4 g SnCl₂·5H₂O/100 ml CaCl₂ solution). The contents of the beaker were quantitatively transferred to a 100 ml volumetric flask and CaCl₂ solution was filtered through a glass filter discarding the first 20 ml and collecting the remaining portion of the filtrate. A clean 2 dm polarimeter tube was filled with the solution and optical rotation measured using a polarimeter.

Starch was calculated using the general formula proposed by Kerr (1950).

Proteins were determined using the bromophenol blue method (BPB) modified by Desborough (1975). The following procedure was used: bovine serum albumin was the standard protein used in a range of 0.25 to 3.0%; 100 mg of freeze-dried potato powder was weighed in a 30 ml centrifuge tube; 10 ml of Hg-BPB solution (0.4 mg BPB/ml of saturated aqueous solution of HgCl₂) was added and the solution mixed immediately with a Vortex mixer. The tube was allowed to stand 30 minutes at room temperature (25°C); the mixture was centrifuged at 5000 g for 15 minutes. The supernatant was transferred to another test tube; 1 ml of supernatant was pipetted into tube containing 10 ml of PO₄ buffer (pH=6.5) and mixed on Vortex. Four undiluted 10 ml Hg-BPB blanks were made before determinations for checking reading variations on a Bausch and Lomb Spectronic 20 colorimeter at 540 nm. The samples were read and optical rotation density readings were subtracted from the standard
average BPB readings to obtain the bound amount of BPB. Percentage of protein was calculated from standard curve (accounting for 11 x dilution).

Reducing sugars were determined by the Munson-Walker general method, an A.O.A.C. method for reducing sugars determinations in plant materials (A.O.A.C. 1975).

Moisture content was determined by freeze-drying during the preparation of the samples. The samples were weighed before and after the drying procedure, and moisture determined by the difference between the weights. Total solids were determined by difference.
CHAPTER 4

RESULTS AND DISCUSSION

In this study 10 potato varieties in four replicates were analyzed to determine their specific gravity, chemical composition, and some of their culinary characteristics. The varieties included 3 standard ones and 7 newly grown in Arizona. The varieties were selected for this study to determine their possible future uses when grown under Arizona environmental conditions. Information is available about characteristics of the varieties grown in other states, but not when grown under Arizona conditions.

The quantitative determinations included specific gravity, moisture, total solids, starch, proteins, and reducing sugars. Chipping quality was determined. Sloughing (disintegration of tubers during cooking) and possible ways to avoid this textural problem were evaluated.

**Specific Gravity**

Specific gravity was determined in all samples on day after harvest (Table 3). The specific gravity values of the 10 varieties ranged from 1.069 to 1.089.

After specific gravity was determined, the varieties were separated into 3 groups. The groups were called A or low specific gravity potatoes (specific gravity from 1.069 to 1.074); group B or medium specific gravity tubers (1.075 to 1.080); and group C or high specific gravity tubers (1.081 to 1.089).
Table 3. Classification and specific gravity of ten selected Arizona-grown potato varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean Specific Gravity</th>
<th>Variance</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Low specific gravity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nebraska S1-3</td>
<td>1.069</td>
<td>$3.50 \times 10^{-6}$</td>
<td>$2.16 \times 10^{-3}$</td>
</tr>
<tr>
<td>Nebraska A63.71-1</td>
<td>1.071</td>
<td>$7.19 \times 10^{-6}$</td>
<td>$3.09 \times 10^{-3}$</td>
</tr>
<tr>
<td>Norgold</td>
<td>1.074</td>
<td>$1.55 \times 10^{-6}$</td>
<td>$1.44 \times 10^{-3}$</td>
</tr>
<tr>
<td>B: Medium specific gravity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red LaSoda</td>
<td>1.077</td>
<td>$5.68 \times 10^{-6}$</td>
<td>$2.75 \times 10^{-3}$</td>
</tr>
<tr>
<td>Nebraska 42-1</td>
<td>1.078</td>
<td>$5.68 \times 10^{-6}$</td>
<td>$2.75 \times 10^{-3}$</td>
</tr>
<tr>
<td>Kennebec</td>
<td>1.079</td>
<td>$2.68 \times 10^{-6}$</td>
<td>$1.89 \times 10^{-3}$</td>
</tr>
<tr>
<td>Nebraska A143.70-2</td>
<td>1.080</td>
<td>$2.75 \times 10^{-6}$</td>
<td>$1.91 \times 10^{-3}$</td>
</tr>
<tr>
<td>C: High specific gravity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nebraska 118</td>
<td>1.086</td>
<td>$4.25 \times 10^{-6}$</td>
<td>$2.38 \times 10^{-3}$</td>
</tr>
<tr>
<td>A-68678</td>
<td>1.086</td>
<td>$2.75 \times 10^{-6}$</td>
<td>$1.91 \times 10^{-3}$</td>
</tr>
<tr>
<td>Denali</td>
<td>1.089</td>
<td>$5.0 \times 10^{-6}$</td>
<td>$8.16 \times 10^{-4}$</td>
</tr>
</tbody>
</table>
gravity tubers (1.084 to 1.089). Each group included varieties with specific gravity within a 0.005 range (Table 3). The reasons for this classification will be explained in the section of tuber sloughing.

Chemical Composition

All samples were analyzed for moisture, total solids, starch, proteins, and reducing sugars. Total solids were determined by two different methods: by difference and by hydrometer. Comparing the two methods, there is no significant difference in the values obtained (Table 4). This confirmed previously published findings which indicate that the determination of specific gravity is an accurate measurement of total solids in potatoes (Smith 1950B).

A standard curve was prepared daily for protein determinations (Fig. 1). All the varieties studied contained higher than average amounts of proteins as shown previously by Talburt et al. (1975). The variations between the different varieties were predicted by their specific gravity and protein in the tuber (Table 5).

Reducing sugars followed a similar pattern to total proteins, decreasing as specific gravity of the tuber increased. The inverse relationship between reducing sugars and specific gravity was shown first by Agle and Woodbury (1968).

The direct relationship between starch content and specific gravity as previously showed by Smith (1977) and Talburt et al. (1975) was confirmed for all varieties in this study.
Figure 1. Standard curve for protein determination using the bromophenol-blue dye binding method and bovine albumin serum as standard protein.
Table 4. Comparison between total solids values obtained using two different methods for determining total solids.

<table>
<thead>
<tr>
<th>Variety</th>
<th>By difference</th>
<th>By hydrometer</th>
<th>Mean</th>
<th>Variance</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nebraska S1-3</td>
<td>17.53</td>
<td>17.82</td>
<td>17.67</td>
<td>$2.1 \times 10^{-2}$</td>
<td>0.201</td>
</tr>
<tr>
<td>Nebraska A63-71-1</td>
<td>17.72</td>
<td>17.89</td>
<td>17.80</td>
<td>$7.22 \times 10^{-3}$</td>
<td>0.121</td>
</tr>
<tr>
<td>Norgold</td>
<td>18.98</td>
<td>18.67</td>
<td>18.82</td>
<td>$2.4 \times 10^{-2}$</td>
<td>0.219</td>
</tr>
<tr>
<td>Red LaSoda</td>
<td>19.07</td>
<td>19.32</td>
<td>19.19</td>
<td>$1.56 \times 10^{-2}$</td>
<td>0.176</td>
</tr>
<tr>
<td>Nebraska 42-1</td>
<td>19.43</td>
<td>19.54</td>
<td>19.48</td>
<td>$3.03 \times 10^{-3}$</td>
<td>0.077</td>
</tr>
<tr>
<td>Kennebec</td>
<td>19.67</td>
<td>19.83</td>
<td>19.75</td>
<td>$6.4 \times 10^{-3}$</td>
<td>0.113</td>
</tr>
<tr>
<td>Nebraska A143.70-2</td>
<td>19.86</td>
<td>20.00</td>
<td>19.93</td>
<td>$4.9 \times 10^{-3}$</td>
<td>0.099</td>
</tr>
<tr>
<td>A-68678</td>
<td>20.29</td>
<td>21.4</td>
<td>20.84</td>
<td>$3.08 \times 10^{-1}$</td>
<td>0.784</td>
</tr>
<tr>
<td>Nebraska 118</td>
<td>21.25</td>
<td>21.4</td>
<td>21.32</td>
<td>$5.62 \times 10^{-3}$</td>
<td>0.106</td>
</tr>
<tr>
<td>Denali</td>
<td>21.83</td>
<td>21.9</td>
<td>21.86</td>
<td>$1.22 \times 10^{-3}$</td>
<td>0.049</td>
</tr>
</tbody>
</table>
Table 5. Approximate composition of selected potato varieties grown in Arizona.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Specific gravity</th>
<th>Moisture (%)</th>
<th>Starch (%)</th>
<th>Proteins (%)</th>
<th>Total sugars (Mg/g dry tissue)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nebraska S1-3</td>
<td>1.069</td>
<td>82.27</td>
<td>12.17</td>
<td>3.06</td>
<td>12.5</td>
</tr>
<tr>
<td>Nebraska A63.71-1</td>
<td>1.071</td>
<td>82.58</td>
<td>11.95</td>
<td>3.08</td>
<td>11.0</td>
</tr>
<tr>
<td>Norgold</td>
<td>1.074</td>
<td>81.02</td>
<td>12.08</td>
<td>2.97</td>
<td>10.5</td>
</tr>
<tr>
<td><strong>Group B:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red LaSoda</td>
<td>1.077</td>
<td>80.93</td>
<td>12.41</td>
<td>2.86</td>
<td>9.5</td>
</tr>
<tr>
<td>Nebraska 42-1</td>
<td>1.078</td>
<td>80.57</td>
<td>12.66</td>
<td>2.74</td>
<td>9.5</td>
</tr>
<tr>
<td>Kennebec</td>
<td>1.079</td>
<td>80.33</td>
<td>12.65</td>
<td>3.01</td>
<td>7.9</td>
</tr>
<tr>
<td>Nebraska A143.70-1</td>
<td>1.080</td>
<td>80.14</td>
<td>13.48</td>
<td>2.52</td>
<td>8.4</td>
</tr>
<tr>
<td><strong>Group C:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-68678-1</td>
<td>1.086</td>
<td>79.71</td>
<td>14.03</td>
<td>2.48</td>
<td>4.9</td>
</tr>
<tr>
<td>Nebraska 118</td>
<td>1.086</td>
<td>78.75</td>
<td>14.61</td>
<td>2.58</td>
<td>3.4</td>
</tr>
<tr>
<td>Denali</td>
<td>1.089</td>
<td>78.17</td>
<td>16.03</td>
<td>2.19</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Chipping Quality

Chipping quality characteristics were determined for all varieties in order to evaluate their suitability for this industrial application.

In this study the 6 varieties having high specific gravity such as Denali, Nebraska 118, A-68678-1, Nebraska A-143.70-2, Kennebec, and Nebraska 42-1 were acceptable for potato chip manufacture (Table 6). According to Davis and Smith (1962), high specific gravity tubers are highly recommended for potato chip manufacture since their content of reducing sugars is usually low enough to avoid browning reactions. The other four varieties (Red LaSoda, Norgold, Nebraska A-63.71-1 and Nebraska S1-3) with the lower specific gravity, produced potato chips of undesirable characteristics. After frying these four varieties, the chips were variable in color, having dark spots in different parts of the slice.

When evaluating potato chips, a scale from 1 to 10 (1=white, 10=burned) is normally used to classify the product. Davis and Smith (1962) found that the consumer preference in terms of color of the product is definite on potato chips with a color value of 4 or lower and uniform.

Sloughing of Potato Tubers

The cooking method developed by Zaehringer et al. (1963) for objective evaluation of potato texture was used in this study. The standard method gives superior uniformity of conditions regardless of specific gravity.
Table 6. Chipping characteristics of 10 selected Arizona-grown varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Chip Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nebraska Sl-3</td>
<td>4 variable</td>
</tr>
<tr>
<td>Nebraska A-63.71-1</td>
<td>4 variable</td>
</tr>
<tr>
<td>Norgold</td>
<td>5 variable</td>
</tr>
<tr>
<td>Red LaSoda</td>
<td>3 variable</td>
</tr>
<tr>
<td>Nebraska 42-1</td>
<td>3</td>
</tr>
<tr>
<td>Kennebec</td>
<td>3</td>
</tr>
<tr>
<td>Nebraska A-143.70-2</td>
<td>4</td>
</tr>
<tr>
<td>A-66678-1</td>
<td>3</td>
</tr>
<tr>
<td>Nebraska 118</td>
<td>3</td>
</tr>
<tr>
<td>Denali</td>
<td>3</td>
</tr>
</tbody>
</table>

Chip color on PCII: 1 to 10 scale (1=white, 10=burned)
The first important parameter for determination of sloughing was cooking duration. Cooking time varied in relationship to tuber specific gravity (or starch content) being longer for low specific gravity potatoes than for medium or high specific gravities.

Two other important parameters in the sloughing study were the soaking period before cooking and the cooking media. The effects of 0, 2, and 4 hour soaking periods in distilled water on sloughing of high, medium and low specific gravity slices were compared (Fig. 2). A soaking treatment before cooking increased the cooked potato weight (CPW). Although the magnitude of the increase in weight varied, a positive effect (decreased sloughing) was always obtained. Tubers of higher specific gravity always sloughed more (decreased CPW) than tubers of medium or low specific gravity. In all cases, tubers soaked for longer periods before cooking sloughed less regardless of their specific gravity. The same results were obtained by Zaehringer et al. (1963). There were minor differences between the varieties of approximately the same specific gravity.

The third parameter was the type of solution used for cooking the soaked tuber slices. Nine different liquids were used as cooking media for all samples. Six were solutions of various salts, the next was the liquid obtained after soaking the slices for 2 hours and the last 2 were mixtures (1:1) of the soaking liquid with each of the 2 salt solutions most effective in reducing sloughing.

Isoconcentrations of the salt solutions were used for each treatment in order to compare the effect of various ions on sloughing. A
Figure 2. Effect of soak period on sloughing for three specific gravity tubers cooked in distilled water.
concentration of 0.005N was chosen because it has been demonstrated by LeTourneau et al. (1962) to induce measurable sloughing. Higher or lower concentrations would emphasize the effect, either positive or negative, caused by the solutions. The results obtained in all nine treatments are summarized in Table 7 and Figures 3, 4, and 5.

Various cations with constant anion identity were used in the first four treatments. Solutions containing either Na or K as the cation caused more sloughing than solutions containing divalent cations (Fig. 3, 4, and 5). Sloughing increased as the specific gravity of the tubers increased. However, a clear difference between those soaked 4 hours before cooking and the unsoaked tubers was obtained. The same tendency for decreasing sloughing was obtained using monovalent ions (Na and K) and distilled water (controls). On the other hand, divalent cations (Mg and Ca) always decreased the rate and amount of sloughing. Calcium was more effective on firming the tubers than Mg.

Previous studies had suggested that the divalent cations are absorbed by cell walls during cooking by reacting with the pectic materials. Because of salts formed, the cell wall gets stronger and resists rupture when starch swells (Keijbets et al. 1976).

When citric acid was used in a cooking media, sloughing increased drastically, especially in tubers soaked longest before cooking. The marked ability of the citrate ion to cause sloughing or otherwise soften potato tissue has been noted by several workers (Davis and LeTourneau 1967, Zaehringer et al. 1963 and 1964) and was confirmed in these experiments.
Table 7. The effect of various salts in the sloughing of tubers previously soaked in distilled water.

<table>
<thead>
<tr>
<th>Salt present in the cooking media</th>
<th>Sloughing (%)</th>
<th>Sloughing (%)</th>
<th>Sloughing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
<td>Group B</td>
<td>Group C</td>
</tr>
<tr>
<td></td>
<td>Time soaked (hrs)</td>
<td>Time soaked (hrs)</td>
<td>Time soaked (hrs)</td>
</tr>
<tr>
<td>None (control)</td>
<td>13.2 9.7 0.3</td>
<td>28.1 24.3 5.1</td>
<td>45.0 33.2 4.8</td>
</tr>
<tr>
<td>0.005N CaCl₂</td>
<td>-0.2 -2.1 -6.8</td>
<td>-4.7 -4.0 -4.6</td>
<td>-5.35 -6.7 -9.3</td>
</tr>
<tr>
<td>0.005N MgCl₂</td>
<td>1.0 -0.8 -1.2</td>
<td>-1.7 -1.9 -6.7</td>
<td>-2.44 -3.98 -4.8</td>
</tr>
<tr>
<td>0.005N NaCl</td>
<td>13.7 6.8 3.9</td>
<td>16.4 11.8 4.3</td>
<td>20.1 13.2 11.0</td>
</tr>
<tr>
<td>0.005N KCl</td>
<td>15.9 9.7 8.6</td>
<td>22.6 13.6 10.7</td>
<td>27.2 15.3 11.1</td>
</tr>
<tr>
<td>0.005N Citric acid</td>
<td>16.3 21.15 26.2</td>
<td>19.1 27.0 33.2</td>
<td>19.7 29.7 42.5</td>
</tr>
<tr>
<td>0.005N NaOH</td>
<td>-1.3 3.1 3.7</td>
<td>0.7 0.96 7.4</td>
<td>-0.33 1.5 15.7</td>
</tr>
<tr>
<td>Soaking liquid</td>
<td>2.3 -4.1 1.46</td>
<td>7.9 -3.7 1.5</td>
<td>6.2 -3.6 6.5</td>
</tr>
<tr>
<td>0.005N Soaking CaCl₂ liquid</td>
<td>-1.3 -7.0 -5.3</td>
<td>-2.3 -4.5 -2.5</td>
<td>-0.7 -4.6 -5.2</td>
</tr>
<tr>
<td>0.005N Soaking MgCl₂ liquid</td>
<td>-0.75 -4.7 -2.33</td>
<td>2.5 0.8 -1.8</td>
<td>4.6 3.0 1.3</td>
</tr>
</tbody>
</table>
Figure 3. Effect of soak period on cooked potato weight for low specific gravity tubers.

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>CaCl₂</td>
</tr>
<tr>
<td>b</td>
<td>MgCl₂</td>
</tr>
<tr>
<td>c</td>
<td>NaCl</td>
</tr>
<tr>
<td>d</td>
<td>KCl</td>
</tr>
<tr>
<td>e</td>
<td>Citric acid</td>
</tr>
<tr>
<td>f</td>
<td>NaOH</td>
</tr>
<tr>
<td>g</td>
<td>Soaking liquid</td>
</tr>
<tr>
<td>h</td>
<td>Ca⁺ soaking liquid</td>
</tr>
<tr>
<td>i</td>
<td>Mg⁺ soaking liquid</td>
</tr>
</tbody>
</table>
Figure 4. Effect of soak period on cooked potato weight for medium specific gravity tubers.
Figure 5. Effect of soak period on cooked potato weight for high specific gravity tubers.
When NaOH was used, a tendency to decrease sloughing in unsoaked slices was seen, but the magnitude was relatively small. In soaked slices, there was also very little sloughing, especially in low specific gravity tubers. The difference NaCl or NaOH appeared to be in sloughing rather than in appearance. In appearance, the slices cooked in NaOH were darker in color and developed an undesirable odor. Solution pH is believed to affect the constituents in the tuber, first by reacting with pigments to produce color change, and then by reacting with nitrogenous compounds to produce odor changes (Fennema 1976).

The soaking liquid was used as the next treatment. In this case, sloughing was reduced only in tubers soaked for 2 hours before cooking. High specific gravity tubers sloughed more than medium and low specific gravity tubers (Fig. 3, 4, and 5). According to Davis and LeTourneau (1967), the main cations lost during soaking are K and Na, but Ca and Mg are also lost. The high concentration of monovalent ions in the soaked liquid was the main cause of sloughing. Calcium and Mg present in the soaking liquid were not able to reduce sloughing because the monovalent cations (K and Na) were prevalent.

If Ca and Mg were needed to reduce sloughing and either soaking liquid and 2 of the salted solutions contained these cations, a mixture of both solutions was able to minimize the effect of monovalent ions present in the soaking liquid (Table 8).

**Calcium and Magnesium Determinations**

Calcium and Mg recovered from the tissue during cooking were determined when the cooking media was the soaking media (Table 8).
Table 8. Calcium and magnesium content of cooking media before and after cooking unsoaked and soaked potato slices.

<table>
<thead>
<tr>
<th></th>
<th>Calcium (mg/l)</th>
<th>Magnesium (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td><strong>Group A:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsoaked slices</td>
<td>57.85</td>
<td>55.48</td>
</tr>
<tr>
<td>Soaked 2 hours</td>
<td>57.85</td>
<td>49.37</td>
</tr>
<tr>
<td>Soaked 4 hours</td>
<td>57.85</td>
<td>51.19</td>
</tr>
<tr>
<td><strong>Group B:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsoaked slices</td>
<td>63.08</td>
<td>56.31</td>
</tr>
<tr>
<td>Soaked 2 hours</td>
<td>63.08</td>
<td>48.17</td>
</tr>
<tr>
<td>Soaked 4 hours</td>
<td>63.08</td>
<td>62.06</td>
</tr>
<tr>
<td><strong>Group C:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsoaked slices</td>
<td>65.48</td>
<td>63.0</td>
</tr>
<tr>
<td>Soaked 2 hours</td>
<td>65.48</td>
<td>56.94</td>
</tr>
<tr>
<td>Soaked 4 hours</td>
<td>65.48</td>
<td>71.13</td>
</tr>
</tbody>
</table>
Calcium and Mg concentrations were higher in soaking liquid obtained from high specific gravity tubers. The amount of divalent cations recovered from the tissue during cooking was always higher in tissue slices soaked for 2 hours in distilled H2O prior to cooking. High specific gravity tubers recovered more Ca and Mg than medium or low specific gravity tubers; however, sloughing had an inverse relationship with the uptake of divalent cations.

There is no evidence in the literature about the determination of Ca and Mg in cooking medias, related to sloughing. This study shows that divalent cations decreased sloughing more effectively in high specific gravity tubers than in lower specific gravity tubers, but only when they were the only cations in the cooking solution. When monovalent cations were also present in the cooking media, the effect was reversed.

Since high specific gravity tubers not only contain more starch, but also the pectic materials appear in the cell wall in very small amounts, divalent cations should affect starch as well as pectic materials. Starch reacts with divalent cations and thereby reduces swelling capacity (Lehninger 1970).

Divalent cations tend to bind starch chains together by metallic bonds. As a result, cell wall pressure of swollen starch granules is decreased since it has been strengthened by the Ca and/or Mg pectinates formed. This reduces the possibility of disintegration of the tuber during cooking (Fig. 6).
Figure 6. Possible effect of salts on sloughing of potato slices previously soaked in water.
CHAPTER 5

CONCLUSIONS

This study provides information about the chemical composition and some of the culinary characteristics of 10 Arizona grown potato varieties. Three standard varieties and 7 new, advanced clones were evaluated after being grown for the first time under Arizona environmental conditions. The results showed different chemical composition between varieties, but all the values were within the range predicted by the specific gravity of the tubers as seen in previous studies. Six of the varieties, 5 new (Nebraska 42-1, Nebraska A-143.70-2, A-68678-1, Nebraska 118, Denali), and 1 standard (Kennebec), had excellent chipping characteristics. The other four, 2 new (Nebraska Sl-3 and Nebraska A-63.71-1), and 2 standard (Norgold and Red LaSoda), were highly recommended for boiling because of the low amount of disintegration during cooking.

Sloughing, the other culinary characteristic measured in this study, was highly reduced when tuber slices were soaked prior to cooking, and then cooked in solutions containing divalent cations. The effect of divalent cations on reducing sloughing had a direct relationship with the amount of starch present in the tubers and their specific gravity. If the observed decrease in sloughing was due to leaching and replacement of ions, than it must be expected that other constituents of the tubers such as starch and intercellular cementing
materials (pectins) could also be influencing the change in tissue composition. The decrease on the rate of tuber disintegration when divalent cations were added may have affected both starch and pectic materials.

There are two practical applications related to sloughing from this study.

1. If sloughing is not desired, the addition of calcium salts for cooking soaked tuber slices or the addition of NaCl to unsoaked slices will highly decrease the disintegration of the tubers on cooking.

2. If sloughing is desired, the addition of citric acid to the cooking media will disintegrate the tubers and facilitate their mashing.
LIST OF REFERENCES


Davies, H. T., and N. C. Dixon, 1976. Evaluation of potato texture by

Davis, W. C., and D. LeTourneau, 1967. Effect of salts on sloughing
of potato slices previously soaked in distilled water. Am.
Potato J. 44:355.

Davis, W. C., and O. Smith, 1962. Potato quality. XXII. Objective
measurement of potato chip color. In Potatoes: Production,
Storing, Processing. 2nd ed., O. Smith (editor). The AVI

Potato Res. 18:273.

Desborough, S., and C. J. Weiser, 1972. Protein comparisons in selected

Dimpler, R., 1962. Determination of optical rotation. In Methods in
Academic Press, New York, N.Y.

N.Y.

Geedes, R., C. Greenwood, and S. Mackenzie, 1965. Studies on the bio-
synthesis of starch granules. Part III. The properties of
the components of starches from the growing potato tuber.
Carbohydrate Res. 1:71.

logical Chemistry. 16th ed., Lange Medical Publications, Los
Altos, CA.

Heinze, P. H., 1956. Cooking quality and compositional factors of

Hoff, J. E., and M. D. Castro, 1969. Chemical composition of potato
cell wall. J. Agric. Fd. Chem. 17:1328.

Hughes, J. C., R. M. Faulks, and A. Grant, 1975A. Texture of cooked
potatoes. Relationship between compressive strength, pectic
substances, and cell size of Redskin tubers of different
maturity. Potato Res. 18:495.

Hughes, J. C., R. M. Faulks, and A. Grant, 1975B. Texture of cooked
potatoes: Relationship between the compressive strength of
cooked potato disks and release of pectic substances. J. Sci.
Fd. Agric. 26:731.
time to breakdown of cooked potato tissue. Am. Potato J.  
54:23.

Kaldy, M. S., and P. Markakis, 1972. Amino acid composition of selected

and their nutritional quality. Potato Res. 18:469.

Keijbets, M. J. H., and W. Pilnik, 1974. Some problems in the analysis 
of pectin in potato tuber tissue. Potato Res. 17:169.

on behaviour of pectic substances in the potato cell wall dur­

Kelly, J. F., 1972. Horticultural crops as sources of proteins and 

demic Press Inc., New York, N.Y.

Kuznetsov, D. I., and L. Nekrasova, 1974. Fatty acid composition and 
lipid content of potato tubers. In Potatoes: Production, 
Co, Inc., Westport, Conn.

Westport, Conn.


quality of potatoes. II. An objective method for evaluating 
texture. Food Tech. 16:135.

and biological value of potato protein fraction. Qual. Plant. 
Mater Veg. 7:290.

some new and standard potato varieties. Division of Food Re­
search, Technical paper No. 37, Melbourne, Australia.


